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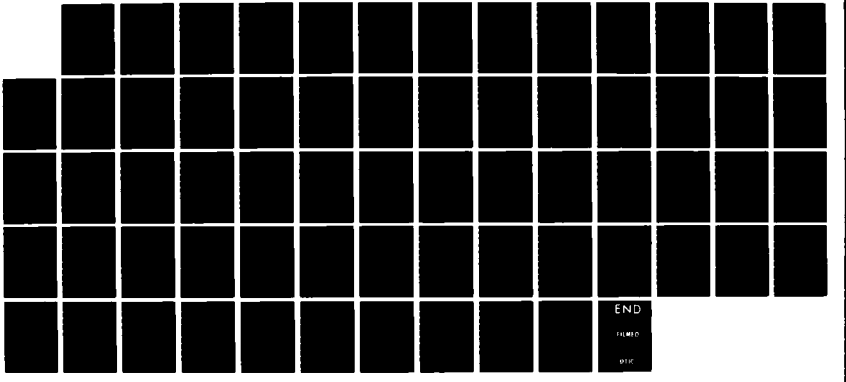

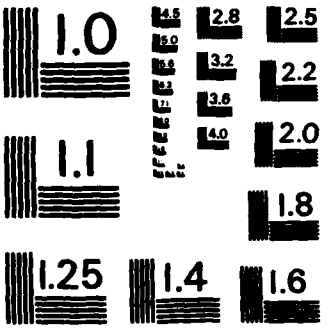

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USERS GUIDE FOR NORMAL MODE OBJECTIVE ANALYSIS OF GLOBAL DATA ASSIMILATION

Shu-Lin Tung

Systems and Applied Sciences Corporation (SASC)
1577 Springhill Road, Suite 600
Vienna, Virginia 22180

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AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

This technical report has been reviewed and is approved for publication.

ALLAN J. BUSSEY
Contract Manager

FOR THE COMMANDER

ROBERT A. McCLATCHEY, Director
Atmospheric Sciences Division

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report is a manual for using the codes that produce the normal mode objective analysis of global data. It describes the procedures for running the codes and provides software documentation. Run streams for the AFGL global spectral model and non-linear normal mode initialization in relation to the analysis procedure are also included. The manual is designed to accompany code listings available from the author.

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BLOCK 11 - TITLE

USERS GUIDE FOR NORMAL MODE OBJECTIVE ANALYSIS OF GLOBAL DATA ASSIMILATION

TABLE OF CONTENTS

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I. GENERAL

An objective analysis using normal mode functions evaluated at irregularly spaced locations was designed and developed to provide initial fields for the AFGL global spectral model. The software for full forecast and analysis cycles was implemented on the Air Force Weapons Laboratory (AFWL) Cray-1 system. The objective of this user manual is to provide an overview of the flow, input requirements, and output capabilities of the objective analysis scheme. Technical details are discussed in Halberstam et al., 1984.[1]

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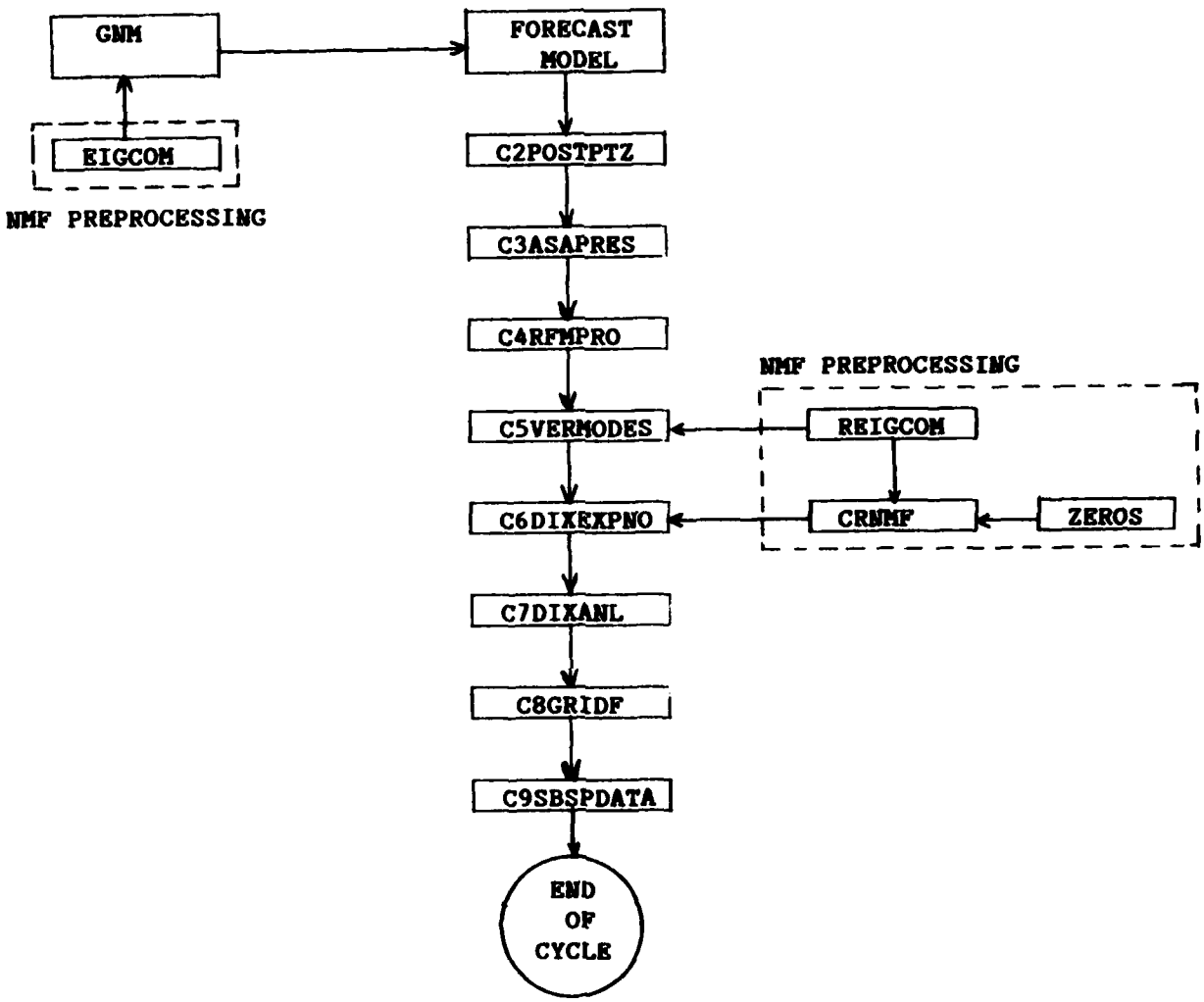
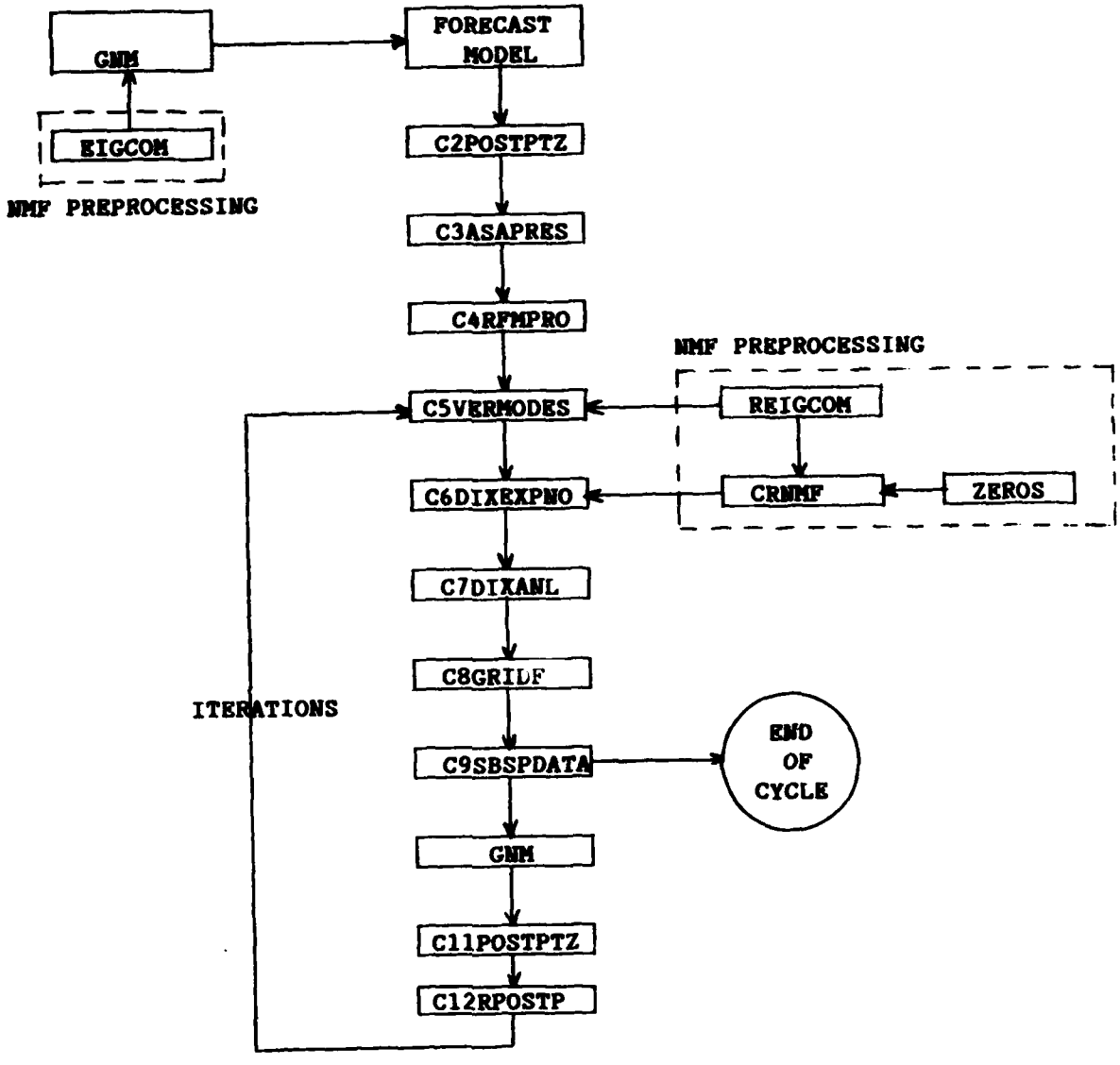
1. Halberstam, ... M., C. Johnson, D. C. Norquist, S.-L. Tung, 1984: Two Methods of Global Data Assimilation. AFGL-TR-84-0260, Contract F19628-82-C-0023, Systems and Applied Sciences Corporation.

II. SYSTEM FLOWCHART

1. System procedures for each analysis cycle without iteration:



2. System procedures with three iterations for each analysis cycle:



III. DOCUMENTATION OF SEQUENTIAL MAIN PROGRAMS

All the programs developed for the analysis cycle are documented in this section. This documentation is written in the following form for each program:

PROGRAM: (Program name)

ABSTRACT: (Abstract of the program)

MAIN SUBROUTINE: (Name of main subroutine or calling subroutine of the program)

SUBROUTINES CALLED: (Name of subroutine used in the program)

INPUT FILES: (Structure and variables for input files in this program)

OUTPUT FILES: (Structure and variables for output files in the program)

DESCRIPTION OF MAIN SUBROUTINE: (Detail of the coding)

PROGRAM: C2POSTPTZ
C11POSTPTZ

ABSTRACT: These programs are set up to process the spectral data from the forecast model to form a first guess grid field for input to program C8GRIDF to reconstruct a new analyzed field. The temperature field is converted to height field by using Sela's method.

MAIN SUBROUTINE: FIELDC(C2POSTPTZ)--input formatted spectral data (coded form)

FIELDB(C11POSTPTZ)--input unformatted spectral data (binary form)

SUBROUTINES CALLED:
LEGSUM
FFT1
PMNS
BSCST
SPTOGP
UMVM
SINMC

INPUT FILES:

1. FORTRAN UNIT 1 - 12 hour forecast spectral coefficients

Record #	Description
1	NSTEP,TIME, ITIME, IDATE FORMAT(I5,F22,A4,A8), if formatted
2	ZMN2(MS,NS,KP) = Vorticity
3	DMN2(MS,NS,KP) = Divergence
4	TMN2(MS,NS,KP) = Temperature
5	WMN2(MS,NS,KP) = Specific humidity
6	QMN2(MS,NS) = Surface pressure
7	GMN2(MS,NS) = Surface geopotential FORMAT(4(1PE20.13)), if formatted for record 2 to 7

OUTPUT FILES:

1. FORTRAN UNIT 2 - First guess grid field

Record #	Description
1 to (NLAT*NHEM)	WTR(MP) = Surface pressure
(NLAT*NHEM+1) to (KP*3+1*NLAT*NHEM) NLAT=Total number of latitudes NHEM=Total number of hemispheres KP=Total number of sigma layers	WTR(MP) = Written in sets of 3 (U, V, and heights) for each sigma layer MP = Total number of longitudes

DESCRIPTION OF MAIN SUBROUTINES:

Designators	Text
CA	Call BSCST to set up constants, resolutions and sigma structure. Call CFFTI to set up Fourier transformation, the dimension of WSAVE is MP*4+15.
CB	Read in the 12 hours forecast spectral data.
CC	Calculate geopotential by using Sela's hydrostatic equations.
CD	Start Loop (DO 6000) over number of latitudes to transform dependent variables from spectral (spherical harmonic) space to grid space. Call SIGNMC to reset the data from AFGL sigma structure (K=1 for top), to NMC sigma structure (K=1 for bottom).
CE	Reset the data structure for output file (tape 2).

PROGRAM: C4RFMPRO

ABSTRACT: This program is designed to reform the residuals file and observations file from the output of program C3ASAPRES.

Both temperature residuals and temperature observation profiles are converted to height residuals and height profiles by using the method of Sela (1982).(2)

Zero residuals are filled in where data are missing. The sounding is rejected if the data from all layers are missing. The update surface pressures are computed by using a quadratic relationship.(1) Four corners method is used to insert the first guess for data-void area.(1)

MAIN SUBROUTINE: RFMZERO

SUBROUTINES CALLED: DTTODZ
GETZERO
TTOZ
GETPS
SETSIG

INPUT FILES:

1. FORTRAN UNIT 1 - Buddy-checked residuals and observations data at observation sites (FGGE II) which output from C3ASAPRES program

Records #	Description
1	NOBS = Number of soundings
Even of (2 to NOBS + 1)	RLAT,RLON,JID,ZSTAR,(UBD(J),J=1,97)

RLAT = Latitude of the observation site
RLON = Longitude of the observation site
JID = Soundings ID
ZSTAR = Surface height
OBD(1) = Surface pressure
OBD(2) = Height residual at level 2
OBD(3) = Quality flag for height
OBD(4) = U wind residual at layer 1
OBD(5) = V wind residual at layer 1
OBD(6) = Quality flag for wind
OBD(7) = Moisture residual at layer 1
OBD(8) = Quality flag for moisture
OBD(9) = Temperature residual at layer 1

2. Sela, J., 1982: The NMC Spectral Model. NOAA Technical Report NWS-30, National Meteorological Center, Washington, D.C.

Records #	Description
	LL=8*(K-1)+1 OBD(LL+1) = Height residual at level K+1 OBD(LL+2) = Quality flag for height OBD(LL+3) = U residual at layer K OBD(LL+4) = V residual at layer K OBD(LL+5) = Quality flag for wind OBD(LL+6) = Moisture residual at layer K OBD(LL+7) = Quality flag for moisture OBD(LL+8) = Temperature residual at layer K
Odd of (2 to NOBS+1)	(TT(J),J=1,KP),X1(J),J=1,KP), (X2(J),J=1,KP),(X3(J),J=1,KP), (TFG(J),J=1,KP) TT = Temperature observation profile X1 = U wind observation profile X2 = V wind observation profile X3 = Specific humidity observations profile TFG = First guess temperature profile

2. FORTRAN UNIT 10 - A matrix and C matrix for Sela's hydrostatic equations [2]

Record #	Description
1	(AM(I,J),I=1,KP),J=1,KP) AM = A matrix
2	(CM(I,J),I=1,KP),J=1,KP) CM = C matrix, (the inverse of AM)* B matrix

OUTPUT FILES:

1. FORTRAN UNIT 5 - Reorganized residual data of U,V wind and composite variable P with equal number of data points at each layer

Record #	Description
(K-1)*KP+1 K = Kth sigma layer KP = Total number of sigma layers	N = Number of soundings for U residuals
(K-1)*KP+2	(OBSLAT(I),I=1,N) Latitudes for U residuals
(K-1)*KP+3	(OBSLON(I),I=1,N) Longitude for U residuals
(K-1)*KP+4	(X(I),I=1,N) U wind residuals

Record #	Description
(K-1)*KP+5	N = Number of sounding for V residuals
(K-1)*KP+6	(OBSLAT(I),I=1,N) Latitude for U residuals
(K-1)*KP+7	(OBSLON(I),I=1,N) Longitude for V residuals
(K-1)*KP+8	(X(I),I=1,N) V wind residuals
(K-1)*KP+9	N = Number of soundings for P (composite variable residuals)
(K-1)*KP+10	(OBSLAT(I),I=1,N) Latitude for P residuals
(K-1)*KP+11	(OBSLON(I),I=1,N) Longitude for P residuals
(K-1)*KP+12	(X(I),I=1,N) P residuals

2. FORTRAN UNIT 15 - Reorganized observation data of U,V wind and temperature with equal number of data points at each layer

Record #	Description
(K-1)*KP+1	N = Number of soundings for U
(K-1)*KP+2	(OBSLAT(I),I=1,N) Latitudes for U observations
(K-1)*KP+3	(OBSLON(I),I=1,N) Longitudes for U observations
(K-1)*KP+4	(X(I),I=1,N) U wind observations
(K-1)*KP+5	N = Number of soundings for V observations
(K-1)*KP+6	(OBSLAT(2),I=1,N) Latitudes for U observations
(K-1)*KP+7	(OBSLON(I),I=1,N) Longitudes for V observations
(K-1)*KP+8	(X(I),I=1,N) V wind observations

Record #	Description
(K-1)*KP+9	N = Number of soundings for temperatures
(K-1)*KP+10	(OBSLAT(I),I=1,N) Latitudes for temperatures
(K-1)*KP+11	(OBSLON(I),I=1,N) Longitude for temperatures
(K-1)*KP+12	(X(I),I=1,N) Temperature observations

DESCRIPTION OF MAIN SUBROUTINE:

Designators	Text
CA	Read in total number of soundings.
CB	Set up sigma structure. (K=1 for bottom)
CC	Read in matrix A and matrix C.
CD	Input residuals, surface height, observations and first guess temperature on each sigma layer.
CE	Check the missing data. If the data of all the layers are missing, the sounding will be dropped. If the data are found on at least one layer, the sounding will be reformatted and stored. The missing residuals will be replaced by zeros and the missing observation temperatures will be replaced by the first guess temperatures.
CF	Sela's method is used in both subroutines DTTODZ and TTOZ to convert temperature residuals to height residuals and temperature profiles to height profiles. Subroutine GETPS is called to compute the surface pressure at observation sites.
CG	The residuals of composite variable are computed from the update surface pressure residuals and height residuals. $\Delta P = \Delta Z*9.8+R*To*\Delta Q$ R = 287.05 To = 300°K basic state temperature.
CH	The useful data are stored in the scratch files tape 2 (residuals) and tape 12 (observations). Subroutine GETZERO is called to apply four corners method to fill in first guess data for data-void area.

PROGRAM: C5VERMODES

ABSTRACT: This program is designed to read data for the sigma layers, then project the data on desired vertical modes.

MAIN SUBROUTINE: VERMOD

SUBROUTINES CALLED: VERT

INPUT FILES:

1. FORTRAN UNIT 1 - U, V, P residuals at sigma layers

   (See output file of program C4RFMPRO)

2. FORTRAN UNIT 5 - Vertical modes

Record #	Description
1	((EIGG(I,J),I=1,KLEV),J=1,MODES), ((EIGT(I,J),I=1,KLEV),J=1,MODES), (GH(I),I=1,MODES),(DOTPRO(I),I=1,MODES), To(I),I=1,KLEV) KLEV = Number of sigma layers MODES = Number of vertical modes EIGG = Eigenvectors of matrix $G^{(3)}$ EIGT = Eigenvectors of matrix G^T GH = Negative of the real eigenvalues of matrix G DOTPRO = Reciprocal of the inner product of eigenvectors of G and G^T To = A vector of basic state temperature

OUTPUT FILES:

1. FORTRAN UNIT 10 - Data projections on vertical modes

Record #	Description
(IMOD-1)*4+1	KOBS,IMODES,IMOD KOBS = Number of soundings IMODES = Number of vertical modes applied IMOD = Mode index (1 to IMODES)
(IMOD-1)*4+2	(RANLAT(J),J=1,KOBS) Latitudes for soundings

---

3. Ballish, A. B., 1980: Initialization, Theory and Application to the NMC Spectral Model. Ph. D. Thesis, University of Maryland, 151 pp.

Record #	Description
(IMOD-1)*4+3	(RANLON(J),J=1,KOBS) Longitude for soundings
(IMOD-1)*4+4	(OBS(J,IMOD),J=KOBS) Data projections of mode IMOD

DESCRIPTION OF MAIN SUBROUTINE:

Designators	TEXT
CA	INPUT vertical modes from Tape 5. INPUT residuals from Tape 1.
CB	Call subroutine VERT to do vertical projection. The projection is located at observations site for each IMOD, up to IMODES.
CC	Write the projections to Tape 10 for output. Print out some values for checking.

PROGRAM: C6DIXEXPNO

ABSTRACT: This program is designed to perform the objective analysis on irregularly spaced observation points by fitting normal mode functions to the residuals (observations minus first guess values) with "finality" procedure.(1) The residuals are first projected onto vertical modes and a set of horizontal normal functions for each vertical mode is evaluated at the same geographic locations as the observations. A set of coefficients is determined by fitting the vectors.

MAIN SUBROUTINE: PCOMP

SUBROUTINES CALLED: GETTH
GETOBS
FUNCH

INPUT FILES:

1. FORTRAN UNIT 1 - DATA projections on vertical modes
(See output files of program C5VERMODES)

2. FORTRAN UNIT 2 - Normal mode functions for every one degree latitude interval

Record #	Description
1	GH = Geopotential of vertical mode IMOD
2	IS,IWG,LR,LALL,IAS IS = Zonal wave number IWG = Gravity wave number LR = Rossby wave number LALL = Accumulated wave number IAS = Index for symmetric (=1) or antisymmetric (=2)
3	(FH(K,1),K=1,NLAT) Normal mode functions for variable U of zonal wavenumber IS and frequency index LALL at every 1 degree latitude
4	(FH(K,2),K=1,NLAT) Normal mode functions for variable V of zonal wavenumber IS and frequency index LALL at every 1 degree latitude

Record #	Description
5	(FH(K,3),K=1,NLAT) Normal mode functions for variable P of zonal wavenumber IS and frequency index LALL at every 1 degree latitude
6	IS,IWG,LR,LALL,IAS
7	(FH(K,1),K=1,NLAT)
8	(FH(K,2),K=1,NLAT)
9	(FH(K,3),K=1,NLAT)
10 to IMODES*NS*NLR*4+1 NS = Total number of zonal waves	Pattern of record #2 to record #5 is repeated for all the zonal wavenumbers and all the frequency indices of each vertical mode IMOD. IMODES=8 is used for case of 12 sigma layers model.

3. FORTRAN UNIT 3 - Total number of gravity waves and Roseby waves to be used of each zonal wave at each vertical mode

Record #	Description
1 to IMODES*NS	NLR = Number of frequency indices for each zonal wavenumber IS and each vertical mode IMOD NL = Maximum of NLR

OUTPUT FILES:

1. FORTRAN UNIT 20 - Resulting coefficients from analysis

Record #	Description
1 to IMODES	A(NL,NS,2) = Coefficients for each vertical mode

DESCRIPTION OF MAIN SUBROUTINE:

Designators	Text
CA	Input resolution and constants.
CB	In loop (DO 1000), vertical modes and normal mode function are read in from Tape 2. For each vertical mode, subroutine GETOBS is called to get data projections of this vertical mode and subroutine GETTH is called to evaluate the normal mode functions on observation sites.
CC	"Finality" procedure is performed in inner loop (DO 5) on all the observation points for each zonal wavenumber (DO 8) and each frequency index (DO 7).

Designators	Text
CD	The coefficient array A(ML,MS,2) is written to Tape 20.
CE	The differences between the input data projections and the computed values from coefficients at the observation sites are printed. The RMS errors are computed for each variable (U, V, P) at each vertical mode.

PROGRAM: C7DIXANL

ABSTRACT: This program is designed to use the coefficients output from C6DIXEXPNO to determine the values of variables at regular grid points[3] (2.5° X 2.5° global grid).

MAIN SUBROUTINE: DIXANL

SUBROUTINE CALLED: None

INPUT FILES:

1. FORTRAN UNIT 3 - Total number of gravity waves and Rossby waves to be used for each zonal wave at each vertical mode
(See FORTRAN UNIT 3 input file for program C6DIXEXPNO.)

2. FORTRAN UNIT 4 - Normal modes functions for every 2.5 degree latitude interval
(The file structure is the same as the structure of input file FORTRAN UNIT 2 for program C6DIXEXPNO.)

3. FORTRAN UNIT 5 - Vertical modes
(See input file FORTRAN UNIT 5 for program C5VERMODES.)

4. FORTRAN UNIT 20 - Analyzed coefficients from the output of program C6DIXEXPNO
(See FORTRAN UNIT 20 of program C6DIXEXPNO.)

OUTPUT FILES:

1. FORTRAN UNIT 30 - Analyzed residuals for each variable (U, V, P) at regular global grids (2.5° X 2.5°) on sigma layers

Record #	Description
1 to KP*NFUN*LHAF	((X(I,J,ILAT,IFUN),I=1,NLON),J=1,2) This record structure is repeated for LHAF latitudes and NFUN variables and KP sigma layers NLON = Number of longitude points (NLON=144 for every 2.5 degree) J = Hemisphere indicator (J=1 for northern hemisphere, J=2 for southern hemisphere)

Record #	Description
	ILAT = Latitude index (ILAT = 1 to LHAF) IFUN = Variable index (IFUN=1 for U wind residuals, IFUN=2 for V wind residuals, IFUN=3 for surface pressure residuals) LHAF = Number of latitudes for one hemisphere (LHAF=37 for every 2.5 degree latitude) NFUN = Number of variables for processing (NFUN=3), i.e., U, V, P (composite variable) or U, V, Q (surface pressure)

DESCRIPTION OF MAIN SUBROUTINE:

Designators	Text
CA	Input for resolutions and constants.
CB	Set up sigma structure and basic state temperature.
CC	Initialize the variable array and input the vertical modes from Tape 5.
CD	Compute the scalar product of the vector function of the sigma coordinates with the vertical mode eigenvector.(3)
CE	Get coefficients SGAM(NL,NS,2) from Tape 20 and get normal mode functions from Tape 4. Residuals for variables (U, V, P) on a 2.5° X 2.5° global grid for each vertical mode IMOD are determined (GRID) and stored in scratch file Tape 1. IMOD ranges from 1 to IMODES (IMODES=8 for KP=12 sigma layers).
CF	At each grid, values on the vertical modes are converted to the values on the sigma layers and composite variables are converted to heights.(3)

PROGRAM: C8GRIDF

ABSTRACT: This program is set up to reconstruct the grid field from analyzed residuals field (2.5° X 2.5°). The updated surface pressure field is computed from updated height field by using a quadratic relationship. The height field is converted to temperature field by using the Flattery method.(1) All the variables are interpolated to updated sigma layers.

MAIN SUBROUTINE: GRIDF

SUBROUTINES CALLED:
PSZTOT
FMTTRA
SETSIG
TOSIG
FLATZT
IMINV

INPUT FILES:

1. FORTRAN UNIT 1 - First guess field (2.5° X 2.5°)

Record #	Description
1 to 74	Q(LON) = Surface pressure LON = Number of points for each latitude circle (LON=144 for every 2.5° longitude) ODD record # is for northern hemisphere and even record # is for southern hemisphere, running from equator to pole
75 to KP*74*3	U(LON) = U wind of each hemisphere for each latitude at each sigma layer V(LON) = V wind of each hemisphere for each latitude at each sigma layer Z(LON) = Z height of each hemisphere for each latitude at each sigma layer These three records are repeated by northern hemisphere to southern hemisphere for 37 latitudes (from equator to pole) for KP=12 sigma layers

2. FORTRAN UNIT 2 - Analyzed residuals at regular global grids (2.5° X 2.5°)
(See output file FORTRAN UNIT 30 of program C7DIXANL.)

OUTPUT FILES:

1. FORTRAN UNIT 10 - The reconstructed global grid of variables U, V and temperature at updated sigma layers

Record #	Description
1 to KP KP=total number of sigma layers	XT(NLON,NLAT) = Temperature on regular global grid (2.5° X 2.5°) for KP=12 sigma layers, where NLON = 144 NLAT = 73
KP+1 to 2*KP	U1(NLON,NLAT) = U on regular global grids (2.5° X 2.5°) for KP=12 sigma layers
2*KP+1 to 3*KP	V1(NLON,NLAT) = V on regular global grid (2.5° X 2.5°) for KP=12 sigma layers
3*KP+1	XQ(NLON,NLAT) = Surface pressure on regular global grid (2.5° X 2.5°)

DESCRIPTION OF MAIN SUBROUTINE:

Designators	Text
CA	Set up constants, resolution, sigma structure and grid locations.
CB	Read in FGGE 3A terrain height field Y(NLON,NLAT) from Tape 4.
CC	Get first guess field of post-processing from Tape 1.
CD	Get analyzed field from Tape 2.
CE	Subroutine SETSIG is called to set up sigma structure. Subroutine FMTTRA is called to rearrange the data structure. Subroutine PSZTOT is called to compute update surface pressure and to convert height field to temperature field. Subroutine TOSIG is called to update variables to new sigma layers with new surface pressure.

PROGRAM: C9SBSPDATA

ABSTRACT: This program converts regular global grid data (2.5° X 2.5°) to spectral data. The regular grids are linearly interpolated to Gaussian latitudes first, then the field is transformed to the spectral domain.

MAIN SUBROUTINE: SPDATA

SUBROUTINE CALLED:
LINTERP
LEGSUM
GAL
LMN
FFT1
PMNS
PRINT
GAUSLAT
POLY

INPUT FILES:

1. FORTRAN UNIT 1 - Regular global grid (see output file FORTRAN UNIT 10 of program C8GRIDF)

2. FORTRAN UNIT 3 - Spectral terrain height from FGGE 3A (rhomboidal truncation)

Records #	*Description*
1	ZMN1(MS,NS,1) = Terrain height in spectral form, where MS=31 and NS=31 for rhomboidal truncation at wavenumber 30

3. FORTRAN UNIT 4 - Specific humidity in spectral form from FGGE 3A (rhomboidal truncation)

Records #	*Description*
1 to KP	ZMN1(MS,NS,KP) = Specific humidity in spectral form for rhomboidal truncation at wavenumber 30 with KP=12 sigma layers

OUTPUT FILES:

1. FORTRAN UNIT 2 - Spectral data of variables vorticity, divergence, temperature, specific humidity, surface pressure and surface geopotential; in coded form with standard structure (See input file FORTRAN UNIT 1 of program C2POSTPTZ.)

DESCRIPTION OF MAIN PROGRAM:

Designators	Text
CA	Set up constants, resolution, Gaussian quadrature and Fourier transform.
CB	U and V grids are linearly interpolated to Gaussian latitudes and are converted to vorticity and divergence in spectral form.
CC	Compute spectral components for temperature.
CD	Merge specific humidity data.
CE	Compute spectral components for surface pressure.
CF	Merge surface geopotential data.

PROGRAM: GNM

ABSTRACT: This program is modified from NMC global forecast model to perform global normal mode initialization.

MAIN SUBROUTINE:

1. GMAIN - This main subroutine is set up to get initial parameters, coefficients constants, model structures and file assignments for model processing. (See GSM program documentation for details[4].)

2. GNMINI - Subroutine is called by subroutine GMAIN to apply Machenhauer method of nonlinear normal mode initialization for global data set. The normal modes with vertical mode less than MODS and period less than PERCUT are adjusted to produce approximately zero tendency.

SUBROUTINES CALLED:

1. GMAIN:
   - SETSIG
   - AMHMTM
   - GLATS
   - EPSLON
   - PRMFLD
   - GRDLNF
   - GSSTCD
   - GNMINI
   - GWRITE

2. GNMINI:
   - RMS
   - BMCM
   - GLOOP
   - TEND
   - VERTIC
   - PRIMES
   - HORIZ1

The details of all these subroutines are described in GSM program documentation.[4] The theory of nonlinear normal mode initialization is discussed in Ballish, 1980[3] and generalization of the scheme is described in Gerlach, 1983.[5]

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4. GSM Program Documentation, NMC/AWS, 1983.

5. Gerlach, A. M. (ed.), 1983: Objective Analysis and Prediction Techniques - 1983. AFGL-TR-83-0333, Contract F19628-82-C-0023, Systems and Applied Sciences Corporation, ADA142441.

INPUT FILES:

1. FORTRAN UNIT 5 - A record containing 28 integers in the format 28I5. These integers fill the array NUM

The details of the array NUM are described in GSM program documentation.[4] The inputs NUM(18) and NUM(19) are used in the initialization scheme.

NUM(18) = MODS; Number of vertical modes to initialize

NUM(19) = NITER: Number of iterations for Machenhauer normal mode initialization

2. FORTRAN UNIT 16 - Inputs for sea surface temperature and drag coefficients

Record #	Description
1	Sea surface temperature with dimension (#LON,#LATG) ordered from equator to poles; sea surface temperature less than 269.95 is considered over land
2	Drag coefficients with dimension (#LON,#LATG) ordered from equator to poles,

where #LON = Number of longitudes for each latitude
#LATG = Number of Gaussian latitudes

Both records are reordered in subroutine ASSTCD from north pole to south pole.

3. FORTRAN UNIT 18 - Spectral data input (unformatted) (See FORTRAN UNIT 1 in program C11POSTPTZ.)

4. FORTRAN UNIT 80 - Inputs for eigenvalues and eigenvectors from the normal mode computation

Record #	Description
1	EIGG,EIGGT,GH,DOTPRO,TO

EIGG(#KP,#KP) = The sorted unit eigenvectors of matrix G
EIGGT(#KP,#KP) = The sorted unit eigenvectors of matrix G^T
GM(#kp) = The negative of the eigenvalues of matrix G
DOTPRO(#KP) = The reciprocal of the inner product of the unit eigenvectors of G and G^T

Record #	Description
	TO(#KP) = A vector of basic state temperatures used in the generation of the normal modes,
	where #KP = Number of vertical layers or modes
2 to #KP*#JCAP1+1	PER,G
where #KP = number of vertical modes	PER(JG) = Periods of gravity modes for each zonal wave and each vertical mode,
#JCAP1=Zonal wave number of rhomboidal truncations #JCAP + 1.	where JG = Number of gravity modes
	G(JG,NAS) = Corresponding eigenvectors,
	where NAS = Vector size of symmetric or antisymmetric This pattern is repeated for #JCAP1 zonal wavenumber and #KP vertical modes.

OUTPUT FILES:

1. FORTRAN UNIT 19 - Normal mode initialized spectral coefficients for all model variables (unformatted) (See FORTRAN UNIT 1 in program C11POSTPTZ.)

DESCRIPTION OF MAIN SUBROUTINES:

See GSM program documentation[4] for details.

PROGRAM: C12RPOSTP

ABSTRACT: This program is set up to compute the update residuals at observation sites. The normal mode initialized field is post-processed at observation sites and combined with original observation data to construct update residuals. Sela's method[2] is used to convert temperature residuals to height residuals.

MAIN SUBROUTINE: RPOSTP

SUBROUTINES CALLED:
LEGSUM
FFTGP
PMNS
BSCST
SPTOGP
UMVM
SIGNMC
GETDZ
DTTODZ

INPUT FILES:

1. FORTRAN UNIT 1 - Normal mode initialized spectral data (unformatted) (See FORTRAN UNIT 1 in program C11POSTPTZ.)

2. FORTRAN UNIT 10 - Observations of U, V wind and temperature with equal number of points on each layer (See FORTRAN UNIT 15 in program C4RFMPRO for details.)

3. FORTRAN UNIT 20 - A matrix and C matrix for Sela's hydrostatic equation (See FORTRAN UNIT 10 in program C4RMFPRO.)

OUTPUT FILES:

1. FORTRAN UNIT 7 - Updated residuals at observation sites

Record #	Description
1	N = Number of observations at layer 1 for U
2	X(I) = Latitudes for U
3	X(I) = Longitudes for U
4	X(I) = U residuals at observation sites on sigma layer 1
5	N = Number of observations on layer 1 for V
6	X(I) = Latitudes for V

Record #	Description
7	X(I) = Longitudes for V
8	X(I) = V residuals at observation sites on sigma layer 1
9	M = Number of observations at layer 1 for composite variable P
10	X(I) = Latitudes for P
11	X(I) = Longitudes for P
12	X(I) = Residuals of composite variable P at observation sites on sigma layer 1

These twelve records are repeated for all sigma layers.

DESCRIPTION OF MAIN SUBROUTINE:

Designators	Text
CA	Set up basic constants and resolutions.
CB	Read in initialized data.
CC	Input for observation locations.
CD	Post-process initialized data at observation sites and store first guess on scratch files.
CE	Check date and compute residuals of variables U, V, T.
CF	Call subroutine GETDZ to get residuals of height then convert to residuals of composite variable. The results are rearranged and written to output file.

PROGRAM: CRNMF

ABSTRACT: This program is designed to calculate the normal mode functions for the AFGL model to be used as basic functions in the analysis of velocities, heights, and surface pressure. The coefficients of vorticity, divergence and the composite variable P are read in from FORTRAN UNIT 1 for the S=0 case and from FORTRAN UNIT 2 for S>0 case. The normal mode functions are stored in FORTRAN UNIT 5. Both Rossby wave and gravitational modes with periods greater than 48 hours are included.

MAIN SUBROUTINE: CRNMF

SUBROUTINES CALLED: MODSUM
PLET
PMMS
WROUT

INPUT FILES:

1. FORTRAN UNIT 1 - The coefficients of vorticity, divergence and composite variable P for S=0

Record #	Description
1	GH(IM) = Height of vertical mode
2 to 3	(PER(I,IAS),I=NF1,NFST), ((G(II,JJ,IAS),II=NFI,NFST), JJ=1,NMER) PER(I,IAS) = Periods for Rossby waves only, where IAS is index of symmetric and antisymmetric modes IAS=1 for symmetric and IAS=2 for antisymmetric G(II,JJ,IAS) = Coefficients for Rossby waves only, where NMER is the number of coefficients found for each eigenvector which includes total of divergence, vorticity and composite variable P

The records 1 to 3 are repeated over all the desired vertical modes IMODES.

2. FORTRAN UNIT 2 - The coefficients of vorticity, divergence and composite variable P for S>0; both Rossby and gravitational modes (whose period exceeds PERCUT) are included

Record #	Description
1	((BLANK(I,J),I=ILEV),J=1,ILEV), ((BLANK(I,J),I=1,ILEV),J=1,ILEV), (GH(I),I=1,ILEV) GH(I) = Height of vertical modes
2 to 3	(PER(I,IAS),I=1,NF),((G(II,JJ,IAS), II=1,NF),JJ=NMER) PER(I,IAS) = Periods for both Rossby waves and gravity waves G(II,JJ,IAS) = Coefficients for both Rossby waves and gravity waves

The record 2 to 3 are repeated over all the zonal waves and all the vertical modes.

OUTPUT FILES:

1. FORTRAN UNIT 5 - The normal mode functions for every 1 degree latitude interval

   (See input file FORTRAN UNIT 2 in program C6DIXEXPNO for details.)

2. FORTRAN UNIT 3 - Total number of gravity waves and Rossby waves to be stored for each zonal wave at each vertical mode

Record #	Description
1 to IMODES*NSWV where IMODES is the total number of vertical modes, NSWV is total number of zonal waves	LALL = Number of frequency indices for each zonal wave and each vertical mode

DESCRIPTION OF MAIN SUBROUTINE:

Designators	Text
CA	Read in all vertical modes.
CB	Write geopotential modal heights to output file.
CC	Read in periods and coefficients.
CD	Compute Legendre functions for all latitudes and specific S.

Designators	Text
CE	Compute normal mode functions for Rossby modes and call subroutine WROUT to write to output file.
CF	Compute normal mode functions for gravitational modes and write to output file.

PROGRAM: ZEROS

ABSTRACT: This program is set up to calculate coefficients of vorticity, divergence, and composite variable for zonal wave S=0.

MAIN SUBROUTINE: ZEROS

SUBROUTINE CALLED: None

OUTPUT FILES:

1. FORTRAN UNIT 1 - The coefficients of vorticity, divergence, and composite variable for S=0

   (See input file FORTRAN UNIT 1 in program NMFUNCTIONS.)

DESCRIPTION OF MAIN SUBROUTINE:

Designators	Text
CA	Input of vertical modes from data statement and output of these to FORTRAN UNIT 1.
CB	Loop over all the Rossby frequencies and fill in sparse vector. Set divergence coefficient to zero.
CC	Perform Gramm-Schmidt procedure.
CD	Compute coefficients of vorticity and composite variable, then write to output file.

PROGRAM: EIGCOM
REIGCOM

ABSTRACT: These programs are set up to compute the normal mode coefficients for use in nonlinear normal mode initialization. The output of program EIGCOM contains only gravity modes. Both Rossby modes and gravity modes are included in REIGCOM output.

The details of these programs are described in GSM program documentation.[4] The basic theory is in Ballish (1980).[3]

IV. DESCRIPTION OF SUBPROGRAMS

The details for those subroutines called by the main programs are discussed in this section. It is written in the following form for each subroutine:

SUBROUTINE: (Name of subprogram)
ABSTRACT: (Abstract of the subroutine)
SUBROUTINES CALLED: (Name of subroutines called by this subroutine)
INPUT VARIABLES: (Variables used as input arguments)
OUTPUT VARIABLES: (Variables used as output arguments)
ARGUMENT LIST: (Variables in argument list)

SUBROUTINE: DTTODZ

ABSTRACT: This subroutine is set up to get height residuals from temperature residuals by using Sela's method.

SUBROUTINES CALLED: None

INPUT VARIABLES:

Symbol	Meaning
DT(K)	Temperature residual profile with dimension KP
KP	Model vertical resolution
CM	C Matrix from Sela's hydrostatic equation (2)
N	Number of observations

OUTPUT VARIABLES:

Symbol	Meaning
DX(k)	Variable to store height residuals with k=1 at bottom
DZ(k)	Computed height residuals from Sela's hydrostatic relation, where k=1 at top

SUBROUTINE: FLATZT

ABSTRACT: This subroutine is set up to apply Flattery's algorithm[1] to get layer temperatures from layer heights. The method involves the construction of thickness temperatures from heights. Using these thickness temperatures, a set of equations is obtained by least-squares approximation that yield temperatures which minimize the errors of the constraining equations.

SUBROUTINE CALLED: IMINV

INPUT VARIABLES:

Symbol	Meaning
ZL(MLP1)	Layer heights
SL(MLP1)	Model sigma layers
MLP1	Number of layers
IWRT	FLAG for printer

OUTPUT VARIABLES:

Symbol	Meaning
TL(MLPL)	Layer temperatures

Description:

DO Loop 20 constructs the reciprocal of the difference across the layers of the logarithm of pressure.

DO Loop 30 sets up coefficients in one set of constraining equations.

DO Loop 40 initializes to zero all the elements of the matrix A transpose, AT(A^T).

DO Loop 50 and 60 set up the coefficients of matrix AT.

DO Loop 80 initializes to zero the elements of the matrix product A^TA or ATA, and then calculates the matrix product.

The thickness temperatures TBAR are computed from the input heights and then the right hand sides of the constraining equations are computed in UNK.

The right hand side of the equations $A\hat{T} = \hat{U}$ is multiplied by A^T.

The solution is obtained by multiplying the inverse of A^TA by A^TU and scaled by multiplying by SCLT.

SUBROUTINE: FMTTRA

ABSTRACT: This subroutine is called to rearrange the data by changing dimension.

SUBROUTINE CALLED: None

INPUT VARIABLES:

Symbol	Meaning
NF1	Original unit number
NF2	Rewrite unit number
A	Original array
NIN	Original dimension
NOUT	Redefine dimension
NLON	Fixed dimension

OUTPUT VARIABLES:

Symbol	Meaning
B	Rearranged array

SUBROUTINE: FUNCH

ABSTRACT: This subroutine is set up to obtain basic function at given latitude from linear interpolation of basic function table. The table is constructed with every one degree latitude intervals.

SUBROUTINE CALLED: None

INPUT VARIABLE:

Symbol	Meaning
PHI	Given latitude
IK	Index for interpolation
X1	Lower bound basic function
X2	Upper bound basic function
IFUN	Function indicator IFUN=1 for U IFUN=2 for V IFUN=3 for Z
IAS	Index for symmetric or antisymmetric modes IAS=1 for symmetric IAS=2 for antisymmetric

OUTPUT VARIABLE:

Symbol	Meaning
XRET	Basic function at given latitude

SUBROUTINE: GETDZ

ABSTRACT: *This subroutine is called to compute residuals for composite variable and construct the output file.*

SUBROUTINE CALLED: DTTODZ

ARGUMENT LIST:

Symbol	Meaning
X	Variable array for input or output
RES	Residual array of composite variable
NALL	Number of data points for each sigma layer
CM	C Matrix from Sela's hydrostatic equation
DX	Height residuals profile from bottom up
DZ	Height residuals profile from top down
QX	Array of surface pressure residuals

SUBROUTINE: GETOBS

ABSTRACT: This subroutine is called to read in normal mode data projections from input file.

SUBROUTINES CALLED: None

ARGUMENT LIST:

Symbol	Meaning
OBS	Array for variable input
KTOTAL	Number of data points for each variable at each vertical mode
ALAT	Array of data latitudes
ALON	Array of data longitudes
CCS	Array of exponentials at data longitudes
NFUN	Number of variables
KFUN	Number of data points for each variable at each vertical mode
KALL	Total number of data points for all the variables at each vertical mode

SUBROUTINE: GETPS

ABSTRACT: This subroutine is set up to obtain updated surface pressures by using quadratic relationship.

SUBROUTINES CALLED: None

INPUT VARIABLE:

Symbol	Meaning
PHI(LAYER)	Height profile with dimension LAYER
LAYER	Number of layers included surface
KP	Number of sigma layers
PO	Model surface pressure
SL	Sigma value at layers
P	Array of log pressure
PP	Array of pressure
N	Number of data points

OUTPUT VARIABLE:

Symbol	Meaning
DQ	Surface pressure residual
PN	Updated surface pressure

SUBROUTINE: GETTH

ABSTRACT: This subroutine is set up to obtain the appropriate horizontal normal mode functions for analysis.

SUBROUTINES CALLED: FUNCH

INPUT VARIABLES:

Symbol	Meaning
FH	Normal mode functions at every one degree latitude intervals
RANLAT	Array of data latitudes
KTOTAL	Number of data points at each sigma layer for all the variables
KFUN	Number of data points at each sigma layer for each variable
NLAT	Not in use
NFUN	Number of variables
IAS	Index for symmetric or antisymmetric

OUTPUT VARIABLE:

Symbol	Meaning
THET	Array of normal mode functions at observation sites

SUBROUTINE: GETZERO

ABSTRACT: This subroutine inserts zero residuals at the corners of a grid box if no observation is found in that box.

SUBROUTINES CALLED: None

ARGUMENT LIST:

Symbol	Meaning
X	Array of data
OBSLAT	Array of latitude
OBSLON	Array of longitude
NALL	Number of data points at each sigma layer
KP	Number of sigma layers
N1	Original unit number of data file
N2	Final unit number of data file
IRES	FLAG for residuals IRES=0 is for observation IRES=1 is for residual
QX	Array of updated surface pressure

SUBROUTINE: IMINV

ABSTRACT: This subroutine is called to compute inverse of matrix. The standard Gauss-Jordan method is used.

SUBROUTINES CALLED: None

INPUT VARIABLES:

Symbol	Meaning
A(N,N)	Input matrix of order N to be inverted; destroyed in computation and replaced by resultant inverse
N	Order of A
L(N)	Work vector of length N
M(N)	Work vector of length N

OUTPUT VARIABLES:

Symbol	Meaning
A(N,N)	Inverse of input matrix A
D	Determinant of A inverse If D=0.0, A is singular

SUBROUTINE: PSZTOT

ABSTRACT: This subroutine is set up to compute updated surface pressure by using quadratic relationship.[1] The updated surface pressure is the input for routine FLATZT to convert height profiles to temperature profiles.

SUBROUTINES CALLED: FLATZT

INPUT VARIABLES:

Symbol	Meaning
PHI(LAYER)	Height profile
LAYER	Number of layers including surface layer
KS	Number of sigma layers
PO	New surface pressure
SL	Sigma values at layers
PL	Update pressures at layers
P	Array of log pressure
PP	Array of pressure
IWRT	FLAG for printer

OUTPUT VARIABLES:

Symbol	Meaning
T(KS)	Updated temperature profile

SUBROUTINE: SETSIG

ABSTRACT: This subroutine is called to set up vertical sigma structure.

SUBROUTINES CALLED: None

Symbol	Meaning
KP	Number of sigma layers
KPP1	KPP1 = KP + 1
KPM1	KPM1 = KP - 1
MK	Not in use
MKM1	Not in use

OUTPUT VARIABLES:

Symbol	Meaning
DEL(KP)	Sigma spacing for layers
SI(KPP1)	1.0-CI at levels
SL(KP)	Sigma values at layers
CI(KPP1)	Sigma values at levels
CL(KP)	1.0-SL at layers

SUBROUTINE: SIGNMC

ABSTRACT: This subroutine is called to change the variables from AFGL sigma structure to NMC sigma structure (index increasing upward).

SUBROUTINES CALLED: None

INPUT VARIABLES:

Symbol	Meaning
U	Array of U
V	Array of V
T	Array of temperature
GZ	Surface geopotential
IHEM	IHEM=1 for northern hemisphere IHEM=2 for southern hemisphere

OUTPUT VARIABLE:

Symbol	Meaning
US	Array of U from surface upward (NMC)
VS	Array of V from surface upward (NMC)
TS	Array of temperature from surface upward (NMC)
GZS	Surface height in meters
DELNMC	DEL from surface upward (NMC)
SINMC	SI from surface upward (NMC)
SLNMC	SL from surface upward (NMC)

SUBROUTINE: TOSIG

ABSTRACT: This subroutine is called to interpolate the variables to new layers with updated surface pressure.

SUBROUTINES CALLED: None

ARGUMENT LIST:

Symbol	Meaning
XP	Array of variable at original vertical layers
XS	Array of variable at updated vertical layers
PS	Updated surface pressure
NLON	Longitudes
KP	Number of new layers
MK	Number of old layers
MKM1	MKM1 = MK - 1
VLNP	Mean of layer log pressures
DLNP	Difference of layer log pressure
SL	Sigma value of vertical structure
PP	Original layer pressures
PL	Updated layer pressures
ALNP	log layer pressures
PM	original surface pressure

SUBROUTINE: TTOZ

ABSTRACT: This subroutine is set up to compute layer heights from layer temperatures by using Sela's hydrostatic relations.[2]

SUBROUTINES CALLED: None

INPUT VARIABLES:

Symbol	Meaning
TT	Layer temperatures from surface upward
ZZ	Layer temperatures from top down
DZ	Layer heights from surface upward
KP	Number of layers
KPP1	KPP1 = KP + 1
CM	C Matrix of Sela's hydrostatic equation
AM	A matrix of Sela's hydrostatic equation
S	Vector for surface height
ZSTAR	Surface height
N	Nth data point

SUBROUTINE: VERT

ABSTRACT: This subroutine is set up to compute the vertical projection of the variable found in the array OBS and to store it in OBS with layers changed to modes.

SUBROUTINES CALLED: None

ARGUMENT LIST:

Symbol	Meaning
OBS	Array of variable
MOBS	Maximum dimension for array OBS to be used in this subroutine
KOBS	Number of data points for the variable
IMODES	Number of vertical modes used
IFUN	Variable indicator IFUN=1 for U IFUN=2 for V IFUN=3 for Z (height)
NLEV	Number of layers

SUBROUTINES:

AFGL IN-HOUSE SUBROUTINES:

BSCST
FFT1
GAUSLAT
GQL
LEGSUM
LINTERP
LMN
PMNS
POLY
PRIN
SPTOGP
UMVM

OI PACKAGE SUBROUTINES: (PROGRAM C3ASAPRES)

ASAP1
MASTOR1
MASTOR4
QCALC
OBTMZL
MASTOR2
MASTOR6
CALCRES
FLAGS
FG
SPTOGPW
LEGSUM
PMNS
UMVM
CQCV
PTOSIG
TLAZLE
FFTGP
SPTOGPX

Not all subroutines from AFGL in-house package or OI package are described in this document.

V. SUMMARY OF RUN STREAM

The run stream for the experiment is summarized in Table 1. This table is an outline from which a procedure file may be developed to implement the run stream. Corresponding COSMOS procedure files for the AFWL Cray-1 computer system are displayed in Figure 1 and Figure 2.

Table 1. Run Stream Table

PROG	NAME	INPUT	OUTPUT	CPU(CRAY)
1	FORECAST MODEL	TAPE2(DRAG COEFS FILE) TAPE8(INITIALIZED SPECIAL DATA)	TAPE7(12 HR FORECAST DATA)*	290 SEC
2	C2POSTPTZ CFFT	TAPE1(12 HR FORECAST DATA)*	TAPE2(FIRST GUESS FIELD)	19 SEC
3	C3ASAPRES	TAPE2(12 HR FORECAST DATA)* TAPE3(FGGE II DATA)* TAPE5(TERRAIN SPECIAL DATA)*	TAPE66(INITIAL RESIDUALS DATA AT OBSERVATION SITES)	345 SEC
4	C4RFMPRO	TAPE1(TAPE66 OF PROG3) TAPE10(SELA'S MATRICES)	TAPE5(RESIDUALS AT OBS SITES AND GRID BOXES) TAPE15(OBSERVATIONS AND FIRST GUESS AT GRID BOXES)	65 SEC
5	C5VERMODES	TAPE1(TAPE5 OF PROG4 OR TAPE7 OF PROG12) TAPE5(NORMAL MODES EIGENVALUES)	TAPE10(DATA PROJECTIONS ON VERTICAL MODES)	35 SEC
6	C6DIXEXPNO	TAPE1(TAPE10 OF PROG5) TAPE2(1°LATITUDE INTERVAL NORMAL MODE FUNCTIONS) TAPE3(NUMBER OF ANALYSIS WAVES)	TAPE20(ANALYZED COEFFICIENTS)	636 SEC
7	C7DIXANL	TAPE3(NUMBER OF ANALYSIS WAVES) TAPE4(2.5° LATITUDE INTERVAL NORMAL MODE FUNCTIONS) TAPE5(NORMAL MODES EIGENVALUES AND EIGENVECTORS TAPE20(TAPE20 OF PROG6)	TAPE30(ANALYZED RESIDUALS AT GRIDS)	68 SEC
8	C8GRIDF	TAPE1(FIRST GUESS FIELD TAPE2 of PROG2 OR PROG11) TAPE2(TAPE30 OF PROG7)	TAPE10(RECONSTRUCTED GRID DATA)	74 SEC
9	C9SBSDATA	TAPE1(TAPE10 OF PROG8) TAPE3(TERRAIN SPECTRAL DATA)* TAPE4(FGGE IIIA SPECIFIC HUMILITY SPECTRAL DATA)	TAPE2(ANALYZED SPECTRAL DATA)	11 SEC

* Indicates formatted file

Table 1. Run Stream Table

PROG	NAME	INPUT	OUTPUT	CPU(CRAY)
10	GMM	TAPE5(ARRAY NUM INPUT) TAPE16(DRAG COEFS FILE) TAPE18(TAPE2 OF PROG9) TAPE80(EIGEN FILE FOR INITIALIZATION)	TAPE19(INITIALIZED SPECTRAL DATA)	32 SEC
11	C11POSTPTZ CFFT	TAPE1(TAPE19 OF PROG10)	TAPE2(FIRST GUESS FIELD)	24 SEC
12	C12RPOSTP	TAPE1(TAPE19 OF PROG10) TAPE10(TAPE15 OF PROG4) TAPE20(SELA'S MATRICES)	TAPE7 (ANALYZED RESIDUALS AT OBS SITES AND GRID BOXES)	378 SEC

```
 1 *select printlo=fctlog,savef=haltung,task=40
 2 *interrupt on softwareerr to stp
 3 *file name=cositr,end=?
 4 *select printlo=igfct<4>,savef=results,task=10
 5 *interrupt on softwareerro to 14
 6 *if <4> .eq. 1 then go to sk1
 7 *xptt / 2
 8 *destroy tape5 fgint
 9 *switch tape2 fgint
10 *mass store fgint:/results/fgint<4>
11 *switch ter31 tape5
12 *let two ="20"
13 *if <1> .ge. 10 then let two = "2"
14 *mass get tape2:fgge\two\<1><2>
15 *file name=input
16  $dtn idate=<1>,itime=<2> $end
17 *xasp / 10
18 *mass store tape66:/results/masp<4>
19 *switch tape5 ter31
20 *go to sk2
21 *sk1: mass get init:/results/init1712z
22 *go to 13
23 *sk2: destroy tape1 tape10 tape15 input
24 *switch tape66 tape1
25 *switch cnat tape10
26 *xc4r / 2
27 *mass store output:/results/c4op<4>
28 *mass store tape5:/results/zeroeq<4> tape15:/results/obseq<4>
29 *switch output c4op<4>
30 *give c4op<4> 1686 end
31 *destroy tape1
32 *let itr=3
33 *switch tape10 cnat
34 *switch tape15 obseq
35 *switch tape5 tape1
36 *switch reig tape5
37 *xver
38 *mass store output:/results/verop\itr\<4>
39 *switch output verop\itr\<4>
40 *give verop\itr\<4> 1686 end
41 *destroy tape1 tape2 tape3 tape20
42 *switch tape10 tape1
43 *switch uvp tape2
44 *switch lall tape3
45 *xdix / 15
46 *mass store output:/results/dixop\itr\<4>
47 *switch output dixop\itr\<4>
48 *give dixop\itr\<4> 1686 end
49 *mass store tape20:/results/rgam\itr\<1><2><3>
50 *copy tape20 tp20\itr\<4>
```

Figure 1. COSMOS procedure file for the experiment run without iteration

```
 51 *give tp20\itr\<4> 1844 end
 52 *destroy tape4
 53 *switch tape2 uvp
 54 *switch uv37 tape4
 55 *xc7d / 2
 56 *mass store output:/results/c7op\itr\<4>
 57 *mass store tape30:/results/rgr\itr\<1><2><3>
 58 *switch output c7op\itr\<4>
 59 *give c7op\itr\<4> 1686 end
 60 *switch tape5 reig
 61 *switch tape3 lall
 62 *switch tape4 uv37
 63 *destroy tape1 tape2 tape10
 64 *switch fgint tape1
 65 *switch tape30 tape2
 66 *switch terht tape4
 67 *xc8g / 2
 68 *mass store output:/results/c8op\itr\<4>
 69 *mass store tape10:/results/grid\itr\<1><2><3>
 70 *switch output c8op\itr\<4>
 71 *give c8op\itr\<4> 1686 end
 72 *destroy tape1 tape2 tape3
 73 *switch tape4 terht
 74 *switch ter31 tape3
 75 *switch sp<4> tape4
 76 *switch tape10 tape1
 77 *xc9s / 4
 78 *mass store output:/results/c9\itr\<4>
 79 *switch output c9op\itr\<4>
 80 *give c9op\itr\<4> 1686 end
 81 *switch tape4 sp<4>
 82 *switch tape3 ter31
 83 *mass store tape2:/results/c9out\itr\<1><2><3>
 84 *destroy tape5 tape16 tape18 tape80 tape19
 85 *switch num tape5
 86 *switch udg tape16
 87 *switch tape2 tape18
 88 *switch eif tape80
 89 *xgnn / 4
 90 *mass store tape19:/results/init\itr\<1><2><3>
 91 *mass store tape6:/results/gnout\itr\<1><2><3>
 92 *switch tape6 t6\itr\<4>
 93 *give t6\itr\<4> 1686 k. end
 94 *switch t6\itr\<4> tape6
 95 *switch tape5 num
 96 *switch tape80 eif
 97 *switch tape16 udg
 98 *mass store tape18:/results/spd\itr\<1><2><3>
 99 *switch tape19 init
100 *destroy tape1 tape2 tape10 output tape20
```

Figure 1. COSMOS procedure file for the experiment run without iteration (continued)

```
101 *13: switch wdg2 tape2
102 *destroy tape8
103 *switch init tape8
104 *destroy tape7 tape1
105 *xfct / 8
106 *destroy tape8
107 *switch tape2 wdg2
108 *let vd=<1>
109 *let vt = "00"
110 *if <2> .eq. "00" then let vt="12"
111 *if vt .eq. "00" then let vd=vd+1
112 *mass store tape7:/results/fct\vd\\vt\
113 *switch tape7 fct\vd\\vt\
114 *give fct\vd\\vt\ 1844 k. end
115 *destroy tape1
116 *go to las
117 *14: go to
118 *las: switch fct\vd\\vt\ tape1
119 ?
120 *mass
121 get ff ter31:terrest3ic num:tape5 wdg:tape16 gnn eif:tape8##
122 wdg2:tape2
123 default dir=/haltung
124 get cnat:cnatrixn reig:reig31x12 uvp:uvpnnfun32 lall:lallnum32#
125 uv37:uvpnnf37lat32 terht:terht144 sp1:sp1712z sp2:sp1800z sp3:sp1812z#
126 sp4:sp1900z sp5:sp1912z sp6:sp21000z
127 set dir=/execute
128 get xdix xfct xc4r xver xc7d xc8g xc9s xptt xasp xgnn
129 end
130 *let inc = 7
131 *let fa=0
132 *let jd = 0
133 *lst: let jd = jd+ 1
134 *if fa then let zt = "00"
135 *if .not. fa then let zt = "12"
136 *cosmos i=cositr with \inc\,\zt\,"z",\jd\
137 *if .not. fa then let inc = inc + 1
138 *let fa = .not. fa
139 *if jd .ge. 5 then go to
140 *go to lst
141 *stp: go to
```

Figure 1. COSMOS procedure file for the experiment run without iteration (continued)

```
 1=*SELECT PRINTLG=CYCLOG,SAVEF=HALTUNG,TASK=90
 2=*INTERRUPT ON SOFTWAREERR TO STP
 3=*FILE NAME=COSITR,END=?
 4=*SELECT PRINTLG=LGITR(4),SAVEF=RESULTS,TASK=10
 5=*INTERRUPT ON SOFTWAREERR0 TO L4
 6=*LET ITR=0
 7=*L1; LET ITR= ITR+1
 8=*SWITCH REIG TAPE5
 9=*XVER
10=*MASS STORE OUTPUT:/RESULTS/TOPVER\ITR\(4)
11=*SWITCH OUTPUT VEROP\ITR\(4)
12=*GIVE VEROP\ITR\(4) 1606 END
13=*DESTROY TAPE1 TAPE2 TAPE3 TAPE20
14=*SWITCH TAPE10 TAPE1
15=*SWITCH UVP TAPE2
16=*SWITCH LALL TAPE3
17=*XDIX / 15
18=*MASS STORE OUTPUT:/RESULTS/TOPDIX\ITR\(4)
19=*SWITCH OUTPUT DIXOP\ITR\(4)
20=*GIVE DIXOP\ITR\(4) 1606 END
21=*MASS STORE TAPE20:/RESULTS/TDAHR\ITR\(1)(2)
22=*COPY TAPE20 TP20\ITR\(4)
23=*GIVE TP20\ITR\(4) 1044 END
24=*DESTROY TAPE4
25=*SWITCH TAPE2 UVP
26=*SWITCH UV37 TAPE4
27=*XC7D / 2
28=*MASS STORE OUTPUT:/RESULTS/TOPC7\ITR\(4)
29=*MASS STORE TAPE30:/RESULTS/TDRR\ITR\(1)(2)(3)
30=*SWITCH OUTPUT C7DP\ITR\(4)
31=*GIVE C7DP\ITR\(4) 1606 END
32=*SWITCH TAPE5 REIG
33=*SWITCH TAPE3 LALL
34=*SWITCH TAPE4 UV37
35=*DESTROY TAPE1 TAPE2 TAPE10
36=*SWITCH FSINT TAPE1
37=*SWITCH TAPE30 TAPE2
38=*SWITCH TERMT TAPE4
39=*XC06 / 2
40=*MASS STORE OUTPUT:/RESULTS/TOPC0\ITR\(4)
41=*MASS STORE TAPE10:/RESULTS/TDRIG\ITR\(1)(2)(3)
42=*SWITCH OUTPUT C00P\ITR\(4)
43=*GIVE C00P\ITR\(4) 1606 END
44=*DESTROY TAPE1 TAPE2 TAPE3 TAPE5
45=*SWITCH TAPE4 TERMT
46=*SWITCH TER31 TAPE3
47=*SWITCH SP(4) TAPE4
```

Figure 2. COSMOS procedure file for the experiment run with three iterations

```
48=*SWITCH TAPE10 TAPE1
49=*SWITCH TTEN TAPE5
50=*XC9S / 4
51=*MASS STORE OUTPUT:/RESULTS/TOPC9\ITR\<4>
52=*SWITCH OUTPUT C90P\ITR\<4>
53=*GIVE C90P\ITR\<4> 1686 END
54=*SWITCH TAPE4 6P<4>
55=*SWITCH TAPE3 TER31
56=*MASS STORE TAPE2:/RESULTS/TOUTC9\ITR\<1><2><3>
57=*DESTROY TAPE5 TAPE16 TAPE18 TAPE80 TAPE19
58=*SWITCH NUM TAPE5
59=*SWITCH UDG TAPE16
60=*SWITCH TAPE2 TAPE18
61=*SWITCH EIF TAPE80
62=*X6NN / 4
63=*MASS STORE TAPE19:/RESULTS/TITIN\ITR\<1><2><3>
64=*MASS STORE TAPE6:/RESULTS/TOUTON\ITR\<1><2><3>
65=*SWITCH TAPE6 T6\ITR\<4>
66=*GIVE T6\ITR\<4> 1686 M. END
67=*SWITCH T6\ITR\<4> TAPE6
68=*SWITCH TAPE5 NUM
69=*SWITCH TAPE80 EIF
70=*SWITCH TAPE16 UDG
71=*MASS STORE TAPE10:/RESULTS/TOPS\ITR\<1><2><3>
72=*SWITCH TAPE19 INIT
73=*DESTROY TAPE1 TAPE2 TAPE10 OUTPUT TAPE20 TAPE3
74=*IF ITR .EE. 3 THEN GO TO L3
75=*SWITCH INIT TAPE1
76=*XC11P / 2
77=*MASS STORE OUTPUT:/RESULTS/TC110P\ITR\<4>
78=*SWITCH OUTPUT C110P\ITR\<4>
79=*MASS STORE TAPE2:/RESULTS/TINTF8\ITR\<4>
80=*SWITCH TAPE3 TTEN
81=*GIVE C110P\ITR\<4> 1686 END
82=*DESTROY TAPE10 TAPE20
83=*SWITCH TAPE2 FGTHT
84=*SWITCH OBSE0 TAPE10
85=*SWITCH CHAT TAPE20
86=*XC12 / 6
87=*MASS STORE OUTPUT/RESULTS/TC120P\ITR\<4>
88=*SWITCH OUTPUT C120P\ITR\<4>
89=*GIVE C120P\ITR\<4> 1686 END
90=*SWITCH TAPE20 CHAT
91=*SWITCH TAPE10 OBSE0
92=*DESTROY TAPE1 TAPE5
93=*LET ITRP= ITR + 1
94=*MASS STORE TAPE7:/RESULTS/TE0ZER0\ITRP\<4>
95=*SWITCH TAPE7 TAPE1
```

Figure 2. COSMOS procedure file for the experiment run with three iterations (continued)

```
 96=*GO TO L1
 97=*L3: SWITCH UBG2 TAPE2
 98=*DESTROY TAPE8
 99=*SWITCH INIT TAPE8
100=*DESTROY TAPE7 TAPE1
101=*XFCT / 8
102=*DESTROY TAPE8
103=*SWITCH TAPE2 UBG2
104=*MASS STORE TAPE7:/RESULTS/TFCST(1)(2)(3)
105=*SWITCH TAPE7 FCST(1)(2)(3)
106=*GIVE FCST(1)(2)(3) 1044 K. END
107=*DESTROY TAPE1
108=*GO TO LAS
109=*L4: GO TO
110=*LAS: SWITCH FCST(1)(2)(3) TAPE1
111=?
112=*MASS
113=GET FF TER31:TERRSST31C NUM:TAPE5 UBG:TAPE16 GNM EIF:TAPEBOB
114=UBG2:TAPE2 FGGE:FGGE20712
115=DEFAULT DIR=/HALTUNG
116=GET CMAT:CMATRIXN RE16:RE1631X12 UVP:UVPNNFUN32 LALL:LALLNUN320
117=UV37:UVPNNF37LAT32 TERNT:TEKNT144 SP1:SP1712Z TAPE1:GSM0712
118=SET DIR=/EXECUTE
119=GET XBIX XFCT XC4R XVER XC7B XC86 XC9S XC11P XC12 XGNM XASP XPTT:XC2
120=END
121=*XPTT
122=*SWITCH TAPE2 FGINT
123=*SWITCH TAPE3 TTEM
124=*MASS STORE FGINT:/RESULTS/TINTFG1
125=*DESTROY TAPE2 TAPE5
126=*SWITCH FGGE TAPE2
127=*FILE NAME=INPUT
128= $DTM IDATE=7,ITIME=12 $END
129=*SWITCH TER31 TAPE5
130=*XASP / 10
131=*MASS STORE TAPE66:/RESULTS/TASAP1
132=*SWITCH TAPE1 BSFCT
133=*DESTROY TAPE10
134=*SWITCH TAPE5 TER31
135=*SWITCH TAPE66 TAPE1
136=*SWITCH CMAT TAPE10
137=*XC4R / 2
138=*MASS STORE TAPE15:/RESULTS/TOBSEB1
139=*DESTROY TAPE1 TAPE20
140=*SWITCH TAPE10 CMAT
141=*SWITCH TAPE15 OBSEQ
142=*MASS STORE TAPE5:/RESULTS/TEBZERB11
143=*SWITCH TAPE5 TAPE1
144=*COSMOS I=COSITR WITH "7" ,"12","2","1"
```

Figure 2. COSMOS procedure file for the experiment run with three iterations (continued)

END

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